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(54) Cathodes for electrochemical cells having additives

(57) A cathode for use in an electrochemical cell having an anode and an electrolyte. The cathode includes a manganese dioxide active material and an additive which includes at least one of SnO_2 , Fe_2O_3 - TiO_2 ,

TiO_2 (P-25), BaTiO_3 , K_2TiO_3 , Nb_2O_5 , or SnO . The cathode of the present invention is particularly adapted for use in an electrochemical cell having a zinc anode and an alkaline electrolyte.

Description

The present invention generally relates to electrochemical cells including cathode additives and more particularly to primary alkaline electrochemical cells having cathodes formed of manganese dioxide, one or more oxide additives, and other cathode components.

Typical alkaline cells include: a steel cylindrical can having a cathode comprising manganese dioxide as the active material, generally formed on the interior surface of the steel can; an anode comprising zinc, generally located in the centre of the cell; a separator film located between the anode and the cathode; and an alkaline electrolyte simultaneously contacting the anode, cathode, and separator. A conductive anode current collector is inserted into the anode active material and a seal assembly closes the open end of the steel can.

A primary goal in the design of alkaline batteries is to increase the service performance of the cell. The service performance is the length of time taken for the cell to discharge under a given load to a specific voltage at which the cell is no longer useful for its intended purpose. One approach which has been taken to increase service performance was to increase the interior volume of the cell in order to increase the amount of active materials within the cell. However, the commercial external size of the cell is fixed, thereby limiting the ability to increase the amounts of active materials within the cell. In order to accommodate more active materials within the cell while maintaining the external size of the cell, the steel label of the conventional alkaline cell has been replaced with one made of thinner metalized plastic film. Thus, the steel can may be enlarged to provide a greater internal volume. By switching to a thinner plastic film label, the service performance of a typical alkaline cell was significantly increased.

Another approach taken to increase the service performance of a cell is to provide for better utilization of the materials of the electrodes. This approach is taken in U.S. Patent No. 5,342,712, which discloses utilizing an anatase titanium dioxide as an additive to a cathode having manganese dioxide as the active material.

Despite past increases in service performance, the need to find new ways to increase service performance remains the primary goal of cell designers.

We have now discovered that the service performance of alkaline cells may be improved by the addition of one or more specific oxide additives to the active cathode material. Thus, the present invention provides an electrochemical cell comprising an anode, a cathode and an electrolyte, in which the cathode of the present invention comprises a manganese dioxide active material and an additive, the additive being one or more of SnO_2 , Fe_2O_3 - TiO_2 , fumed TiO_2 [which is preferably TiO_2 (P-25)], BaTiO_3 , K_2TiO_3 , Nb_2O_5 , Al_2O_3 , WO_3 , CoTiO_3 , SrTiO_3 , SnO , or V_2O_5 .

The cathode of the present invention is particularly adapted for use in an electrochemical cell having a zinc

anode and an alkaline electrolyte.

In a preferred embodiment, the additive constitutes from 0.1 to 10 weight percent of said cathode, preferably from 1 to 5 weight percent of said cathode and more preferably from 1 to 2 weight percent of said cathode.

The invention is further illustrated by reference to the accompanying drawings, in which:

Figure 1 is a cutaway perspective view of an example of an electrochemical cell constructed in accordance with the present invention;

Figure 2 is a comparative graph of the service performance of a standard alkaline cell having a cathode with no additives and electrochemical cells having cathodes with additives in accordance with the present invention;

Figure 3 is a comparative graph of the service performance of a standard alkaline cell having a cathode with no additives and electrochemical cells having cathodes with additives in accordance with the present invention;

Figure 4 is a comparative graph of the service performance of a standard alkaline cell having a cathode with no additives and an electrochemical cell having a cathode with an additive in accordance with the present invention; and

Figure 5 is a comparative graph of the service performance of a standard alkaline cell having a cathode with no additives and an electrochemical cell having a cathode with an additive in accordance with the present invention.

Figure 1 shows a cutaway view of a typical cylindrical alkaline battery 10. Alkaline battery 10 includes a steel can 15 having a cylindrical shape and one open end. A metalized, plastic film label 16 is formed about the exterior surface of steel can 15 except for the ends of steel can 15. At the closed end of steel can 15 is a positive cover 17 preferably formed of plated steel. Film label 16 is formed over the peripheral edge of positive cover 17.

A cathode 20 preferably formed of a mixture of manganese dioxide, graphite, 45% potassium hydroxide solution, deionized water, a TEFLON™ solution, and an additive, is formed about the interior side surface of steel can 15. A separator 30, which is preferably formed of a non-woven fabric that prevents migration of any solid particles in the battery, is disposed about the interior surface of cathode 20. An electrolyte 40 preferably formed of potassium hydroxide is disposed in the interior of separator 30. An anode 50, preferably formed of zinc powder, a gelling agent and other additives, is disposed with in electrolyte 40 in contact with a current collector 60, which may be formed, for example, of brass.

Current collector 60 contacts a brass rivet 70 formed at the open end of steel can 15. A nylon seal 71 is formed at the open end of steel can 15 to prevent leakage of the active ingredients contained in steel can 15. Nylon seal 71 contacts a metal washer 72 and an inner cell cover 74, which is preferably formed of steel. A negative cover 75, which is preferably formed of plated steel, is disposed in contact with inner cell cover 74 and brass rivet 70, which contacts current collector 60 through a hole formed in nylon seal 71. Negative cover 75 is electrically insulated from steel can 15 by nylon seal 71.

The cathode of the present invention for a D-size cell is preferably composed of approximately from 71.76 to 81.66 weight percent MnO_2 , about 8.52 weight percent graphite, about 7.87 weight percent of an alkaline solution, such as a 45% KOH solution, about 0.36 weight percent deionized water, about 1.49 weight percent binder material, such as a TEFLON™ solution, and approximately from 0.1 to 10 weight percent of an additive. More preferably, the weight percent of MnO_2 is between about 76.76 and 80.76 and the weight percent of the additive is between 1 and 5, such that the combined weight percent of MnO_2 and the additive is a constant of preferably approximately 81.76. The amount of alkaline solution used in the cathode varies according to cell size as does the amount of the binder material. Preferably, the additive is SnO_2 , but the additive may, instead or as well, include one or more of SnO , BaTiO_3 , K_2TiO_3 , Al_2O_3 , $\text{Fe}_2\text{O}_3\text{-TiO}_2$, filmed TiO_2 [TiO_2 (P-25)], WO_3 , SrTiO_3 , CoTiO_3 , Nb_2O_5 , or V_2O_5 .

TiO_2 (P-25) is a fumed titanium dioxide available from Degussa Corporation. Unlike most forms of titanium dioxide, which are produced using a precipitation technique, TiO_2 (P-25) is produced by high temperature (> 1200°C) flame hydrolysis of TiCl_4 in the presence of O_2 and H_2 . From the burner, a coagulation of primary particles takes place during cooling which results in the final particle size and distribution. A series of cyclones separates the solid material from reaction gases. The product is then subjected to steam to remove HCl which is a by-product from the reaction. TiO_2 (P-25) is non-porous and has a particle shape that is cubic in nature with rounded edges. Crystallographic study of TiO_2 (P-25) shows that multiphases of amorphous, anatase and rutile forms exist. The anatase-to-rutile ratio is between 70:30 and 80:20.

Thus, a preferred form of fumed TiO_2 is a mixture comprising a combination of the anatase and rutile forms of TiO_2 in which the anatase-to-rutile ratio is preferably from 70:30 to 80:20.

The cathode can be made, for example, by the following procedure: weighing out the needed materials and mixing the MnO_2 , the additive, and the graphite and blending to obtain a homogeneous mixture. Then, the deionized water, the TEFLON™ solution and the KOH solution are mixed with the dry cathode components to form a homogeneous cathode mix. The cathode mixture

is then placed in steel can 15 and moulded into an annular, cylindrical shape.

As stated above, it has been discovered that the addition of small amounts of the above listed additives significantly increases the service performance of alkaline electrochemical cells. The following examples illustrate the advantages obtained from practicing the present invention.

EXAMPLE 1

A control alkaline D-size cell was prepared as described above except that no additive was included in the cathode and the weight percentage attributed to the additive was provided by additional MnO_2 . Thus, the composition of the cathode in the control cell was approximately 81.76 weight percent MnO_2 , about 8.52 weight percent graphite, about 7.87 weight percent of a 45% aqueous solution of potassium hydroxide (KOH), about 0.36 weight percent deionized water, and about 1.49 weight percent of a TEFLON™ binder solution. A first experimental D-size cell having a cathode with 1.6 weight percent SnO_2 (in place of the corresponding amount of MnO_2), a second experimental D-size cell having the same amount of an additive of $\text{Fe}_2\text{O}_3\text{-TiO}_2$, and a third experimental D-size cell including the same amount of a TiO_2 (P-25) additive were also constructed. The four cells were continuously connected to a 1.0 Ohm load and the voltages of the cells were measured over a period of time. Figure 2 shows a graph of the time versus voltage discharge profiles of the four cells. At a cutoff voltage of 0.75 volt, the first experimental cell including the SnO_2 additive exhibited a 24% increase in service performance over the control cell. The second experimental cell including the $\text{Fe}_2\text{O}_3\text{-TiO}_2$ additive, and the third experimental cell including the TiO_2 (P-25) additive both had a 9% increase in service performance over the control cell.

EXAMPLE 2

A fourth experimental D-size cell having a BaTiO_3 additive and a fifth experimental D-size cell having a K_2TiO_3 additive were constructed, along with a control cell having no additive. In both cells containing additives, the amount was 1.6 weight percent. The three cells were connected to a 2.2 Ohm load for one hour per day. Figure 3 shows the resulting time versus voltage discharge profiles for the three cells. For a 1.00 volt cutoff, the fifth experimental cell with the K_2TiO_3 additive showed a 10% increase over the service performance of the control cell and the fourth experimental cell having the BaTiO_3 additive exhibited an 8% increase in service performance over the control cell. At a 0.80 volt cutoff, the fifth experimental cell having the K_2TiO_3 additive had a 13% increase in service performance over the control cell, while the fourth experimental cell had a 10% increase in service performance over the control cell.

EXAMPLE 3

A sixth experimental D-size cell having a Nb_2O_5 additive in an amount of 1.6 weight percent, and a control cell having no additive were constructed and subjected to a 2.2 Ohm light intermittent flashlight (LIF) test, whereby the cells were connected to a 2.2 Ohm load for four minutes per hour for eight consecutive hours per day. Figure 4 shows the resulting time versus voltage discharge profiles for the sixth experimental cell and the control cell. At a 1.00 volt cutoff, the sixth experimental cell showed no improvement in service performance over the control cell. However, at a 0.90 volt cutoff, the sixth experimental cell had a 7 % increase in service performance over the control cell.

EXAMPLE 4

A control alkaline AA-size cell was prepared as described above using the same weight percentages as used for the control D-size cell except no additive was included in the cathode and the weight percentage attributed to the additive was provided by additional MnO_2 . A seventh experimental AA-size cell having a cathode with 1.6 weight percent SnO_2 and an eighth experimental AA-size cell having the same amount of an additive of TiO_2 (P-25) additive were also constructed. The three cells were subjected to an IEC photoflash test by connecting the cells to a 1.8 Ohm load for cycles of fifteen seconds ON and forty-five seconds OFF (i.e., each cycle equaling one minute) and the voltages of the cells were measured over a period of ON/OFF cycles. Figure 5 shows a graph of the cycle versus voltage discharge profiles of the three cells. At a cutoff voltage of 0.9 volt, the seventh experimental cell including the SnO_2 additive exhibited a 25 % increase in service performance over the control cell. The eighth experimental cell including the TiO_2 additive had a 15 % increase in service performance over the control cell.

As is apparent from the above examples, significant increases in service performance of an alkaline electrochemical cell may be obtained using additives of SnO_2 , $\text{Fe}_2\text{O}_3\text{-TiO}_2$, TiO_2 (P-25), BaTiO_3 , K_2TiO_3 , and Nb_2O_5 . Increases in service performance have also been obtained using additives of SnO , Al_2O_3 , WO_3 , SrTiO_3 , CoTiO_3 , and V_2O_5 .

Although the above examples were restricted to D and AA-size cells, it will be appreciated by those skilled in the art that the increase in service performance may be obtained regardless of the size of the cell. Because some of the above additives perform better than others in continuous tests while others perform better in intermittent tests, it is desirable to combine such additives to enhance the overall service performance of an electrochemical cell for both continuous and intermittent use.

Claims

1. An electrochemical cell having an anode, a cathode, and an electrolyte, said cathode comprising a manganese dioxide active material and an additive, characterised in that the additive comprises one or more of SnO_2 , $\text{Fe}_2\text{O}_3\text{-TiO}_2$, fumed TiO_2 , BaTiO_3 , K_2TiO_3 , Nb_2O_5 , Al_2O_3 , WO_3 , CoTiO_3 , SrTiO_3 , SnO , and V_2O_5 .
2. An electrochemical cell according to claim 1, wherein said anode includes zinc and the electrolyte is an alkaline electrolyte.
3. An electrochemical cell according to claim 1, wherein said additive constitutes from 0.1 to 10 weight percent of said cathode.
4. An electrochemical cell according to claim 3, in which said additive constitutes from 1 to 5 weight percent of said cathode.
5. An electrochemical cell according to claim 4, in which said additive constitutes from 1 to 2 weight percent of said cathode.
6. An electrochemical cell according to any one of claims 1 to 5, in which said additive comprises fumed TiO_2 .
7. An electrochemical cell according to any one of claims 1 to 5, in which said additive comprises a combination of anatase and rutile TiO_2 .
8. An electrochemical cell according to claim 7, wherein said combination of anatase and rutile TiO_2 includes at least 20 percent rutile TiO_2 .
9. An electrochemical cell according to any one of claims 1 to 5, in which said additive comprises Nb_2O_5 .
10. An electrochemical cell according to any one of claims 1 to 5, in which said additive comprises SnO .
11. An electrochemical cell according to any one of claims 1 to 5, in which said additive comprises SnO_2 .
12. An electrochemical cell according to any one of claims 1 to 5, in which said additive comprises $\text{Fe}_2\text{O}_3\text{-TiO}_2$.
13. An electrochemical cell according to any one of claims 1 to 5, in which said additive comprises BaTiO_3 .
14. An electrochemical cell according to any one of

claims 1 to 5, in which said additive comprises K_2TiO_3 .

15. An electrochemical cell according to any one of claims 1 to 5, in which said additive comprises Al_2O_3 . 5

16. An electrochemical cell according to any one of claims 1 to 5, in which said additive comprises WO_3 . 10

17. An electrochemical cell according to any one of claims 1 to 5, in which said additive comprises $CoTiO_3$.

18. An electrochemical cell according to any one of claims 1 to 5, in which said additive comprises $SrTiO_3$. 15

19. An electrochemical cell according to any one of claims 1 to 5, in which said additive comprises V_2O_5 . 20

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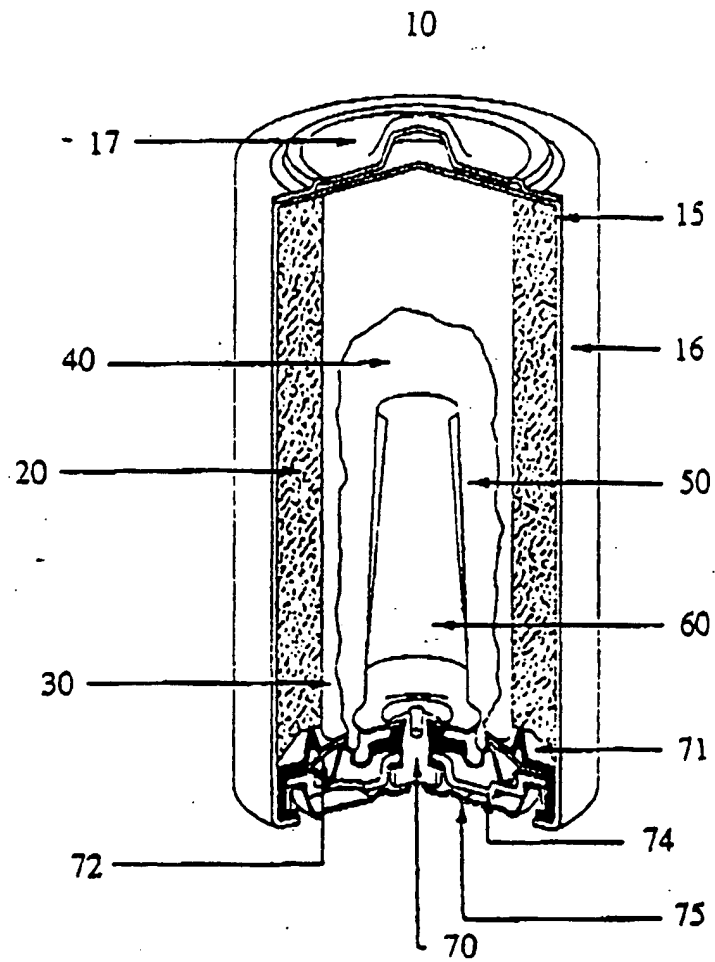


FIG. 1

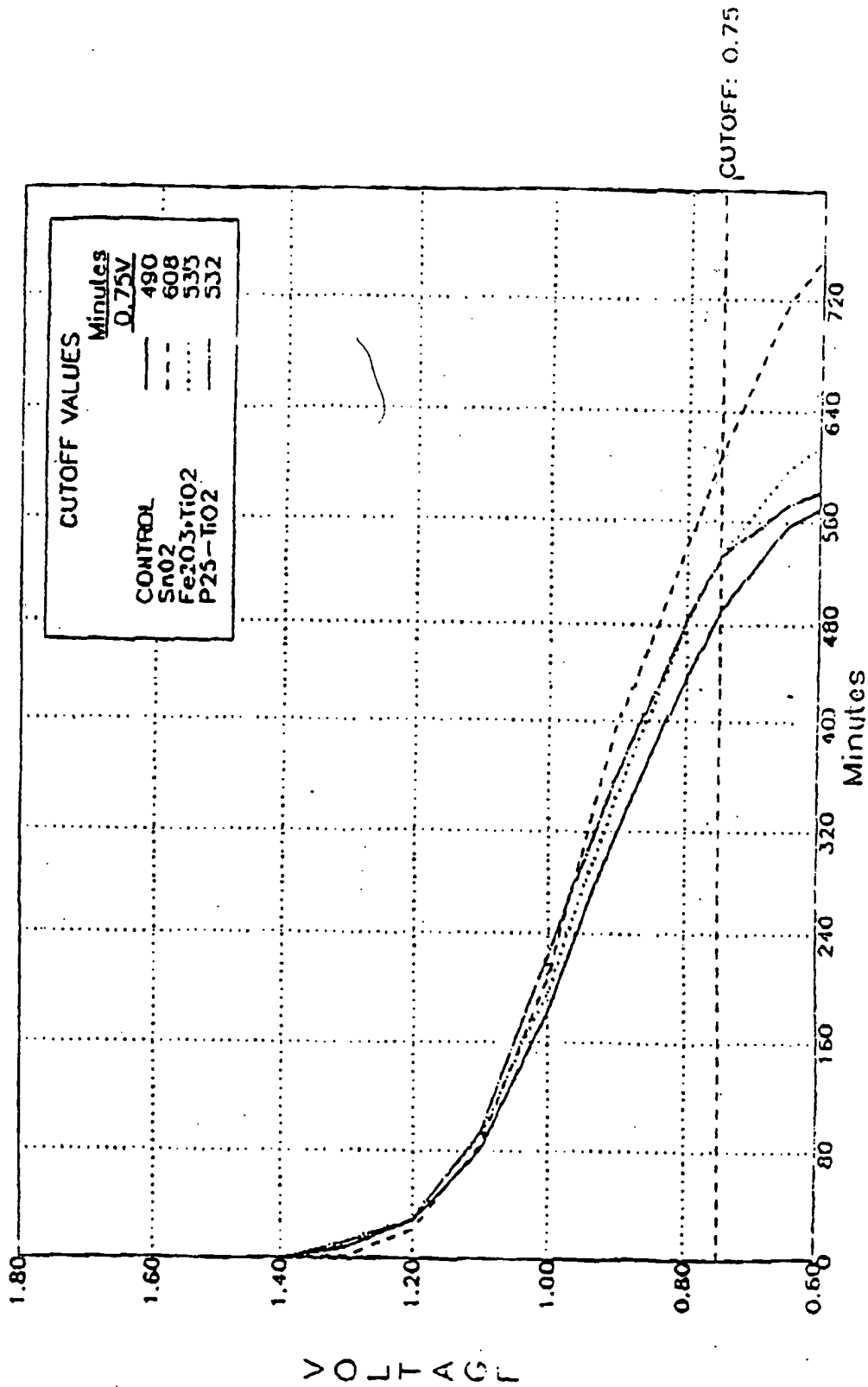


FIG. 2

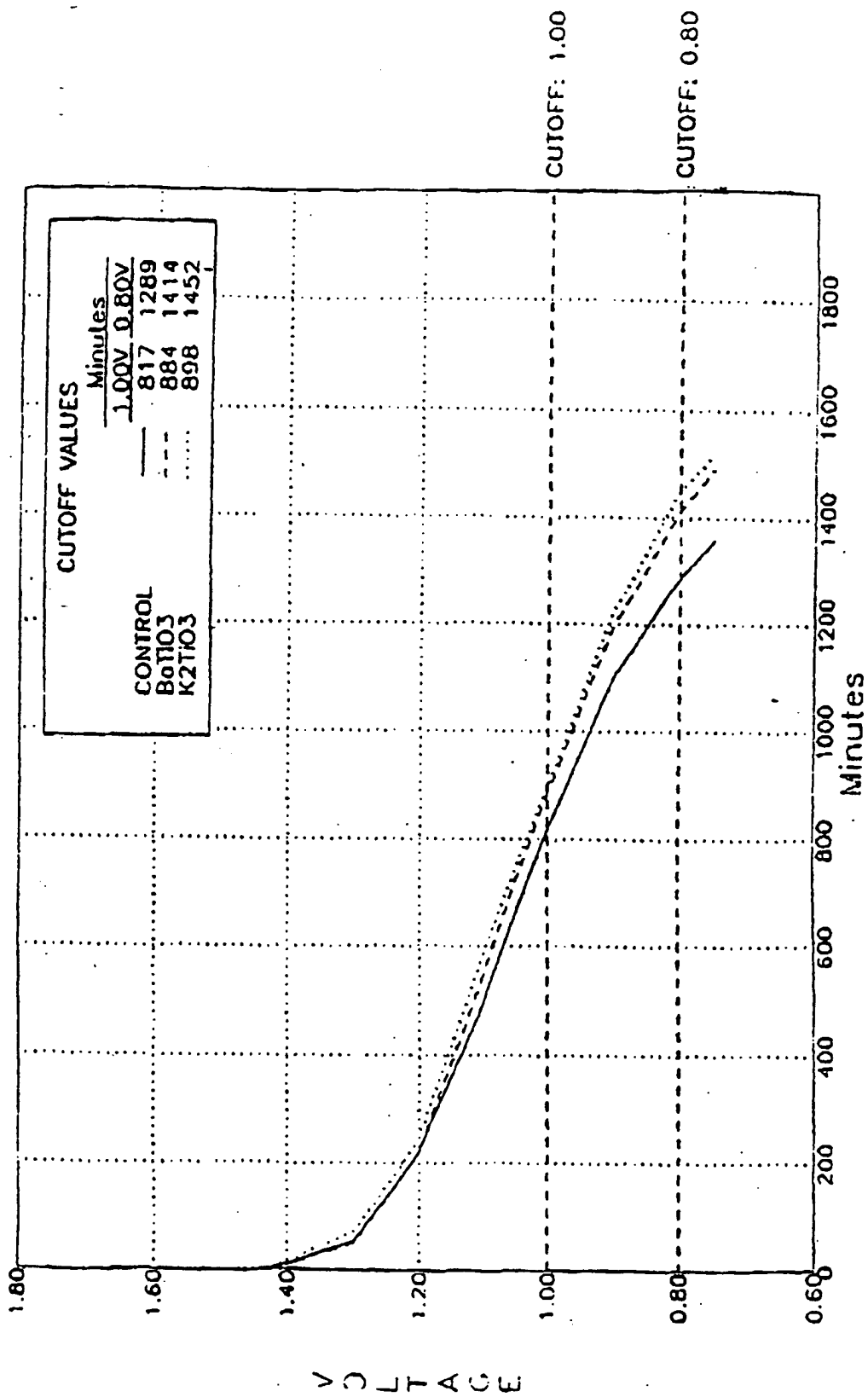


FIG. 3

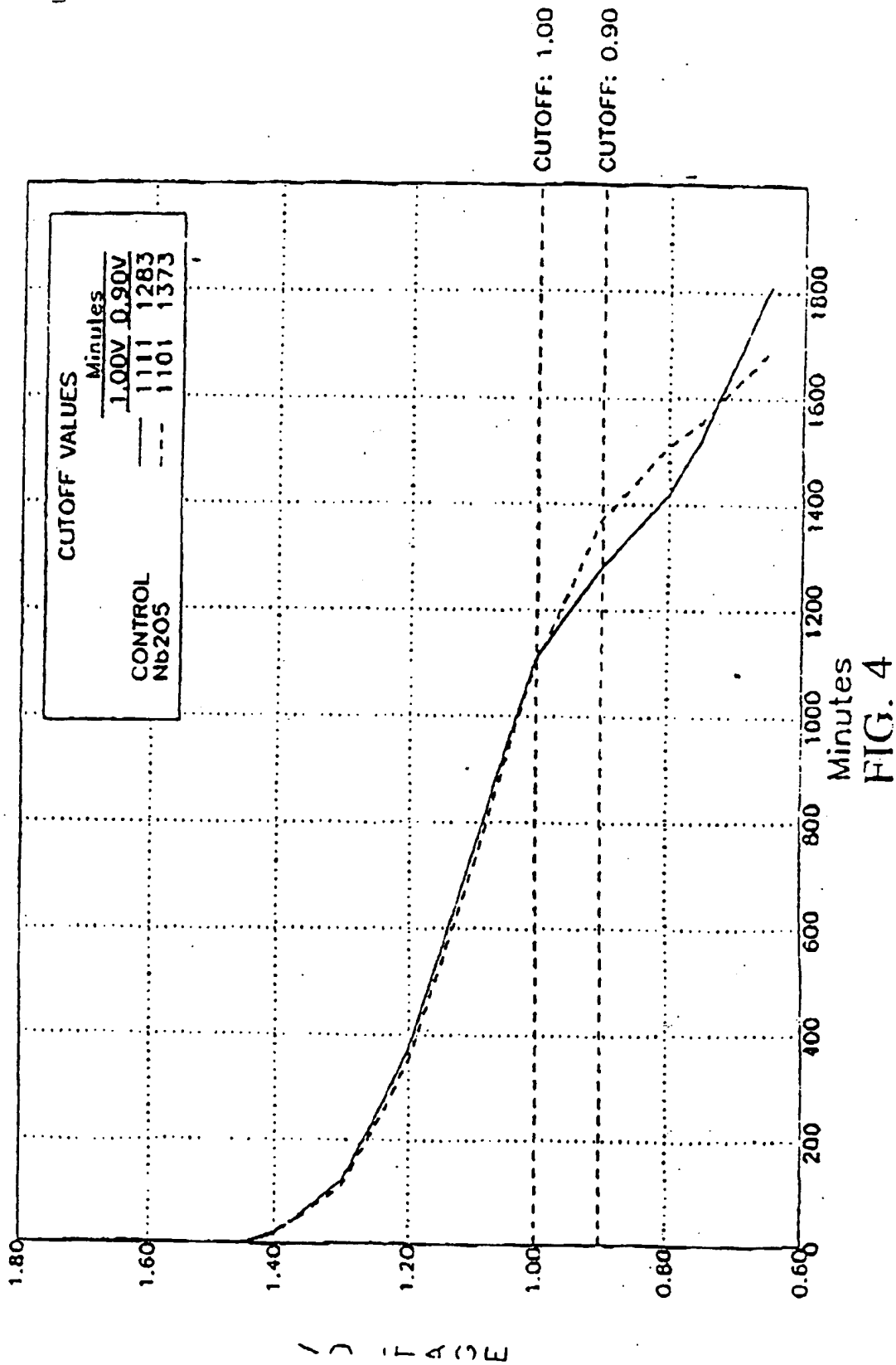
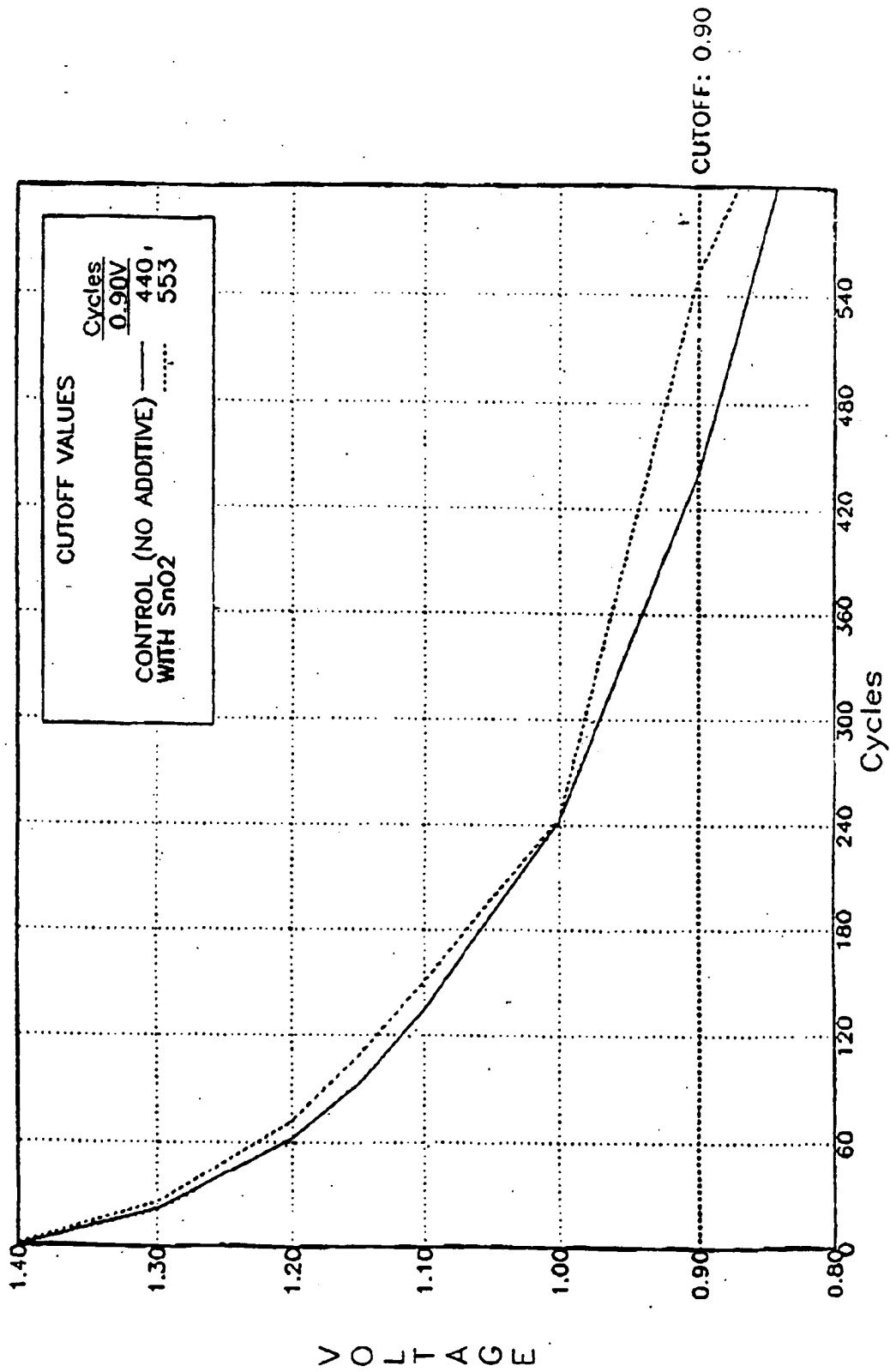


FIG. 5





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| DOCUMENTS CONSIDERED TO BE RELEVANT | | | |
|---|--|---|--|
| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int.Cl.6) |
| X | US-A-4 549 943 (MELLORS GEOFFREY W) 29 October-1985 * column 4, line 44 - line 59; claims 1,7 * table I * * example 2; table II * * example 4; table IV * --- | 1-3,11,16 | H01M4/50 H01M4/62 |
| X | WO-A-92 17910 (BATTERY TECHNOLOGIES INC) 15 October 1992 * page 7, last paragraph; claims 1,2 * * page 6, paragraph 4 * --- | 1-5,19 | |
| X | US-A-3 257 242 (JOACHIM EULER ET AL) 21 June 1966 * example 3 * --- | 1,3,4,19 | |
| X | DE-A-29 37 285 (HITACHI CHEMICAL CO LTD; HITACHI LTD) 27 March 1980 * claim 9 * --- | 1,19 | |
| X | US-A-4 465 747 (EVANS WILLIAM P) 14 August 1984 * claims 1-3 * --- | 1,3,4,13,14,18 | TECHNICAL FIELDS SEARCHED (Int.Cl.6) H01M |
| X | US-A-4 478 921 (LANGAN RICHARD A) 23 October 1984 * claim 4 * --- | 1,3,4,13,14,18 | |
| X | DATABASE WPI Section Ch, Week 8128 Derwent Publications Ltd., London, GB; Class A85, AN 81-50867D XP002012847 & JP-A-56 061 771 (NIPPON ELECTRIC KK) , 27 May 1981 * abstract * --- | 1,11,19 | |
| | | -/-- | |
| The present search report has been drawn up for all claims | | | |
| Place of search THE HAGUE | | Date of completion of the search 17 September 1996 | Examiner D'hondt, J |
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Application Number
EP 96 30 4263

| DOCUMENTS CONSIDERED TO BE RELEVANT | | | |
|---|--|----------------------------------|--|
| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int.Cl.6) |
| X | DATABASE WPI Section-Ch, Week 8147 Derwent Publications Ltd., London, GB; Class A85, AN 81-86344D XP002013459 & JP-A-56 130 082 (TOSHIBA DENCHI KK) , 12 October 1981 * abstract * & PATENT ABSTRACTS OF JAPAN vol. 6, no. 9 (E-090), 20 January 1982 * abstract * | 1,3-5 | |
| X | --- WO-A-85 01615 (ACR ELECTRONICS) 11 April 1985 * claim 13 * | 1,15 | |
| X | --- CHEMICAL ABSTRACTS, vol. 106, no. 22, 1 June 1987 Columbus, Ohio, US; abstract no. 179816, YAMAMOTO, TAKAKAZU: "Secondary zinc-manganese oxide battery" XP002013457 * abstract * & JP-A-61 294 768 (JAPAN) --- | 1,15 | |
| A | --- US-A-5 077 150 (YONEDA TETSUYA) 31 December 1991 * claim 10 * --- -/-- | 1,16 | |
| The present search report has been drawn up for all claims | | | |
| Place of search | | Date of completion of the search | Examiner |
| THE HAGUE | | 17 September 1996 | D'hondt, J |
| CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application I : document cited for other reasons & : member of the same patent family, corresponding document | | | |



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Application Number
EP 96 30 4263

| DOCUMENTS CONSIDERED TO BE RELEVANT | | | |
|--|---|---|--|
| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int.Cl.6) |
| A | CHEMICAL ABSTRACTS, vol. 107, no. 26, 28 December 1987 Columbus, Ohio, US; abstract no. 239778, YAMAMURA, KAZUAKI ET AL: "Manufacture of manganese dioxide for batteries" XP002013458 * abstract * & JP-A-62 187 118 (CHUO DENKI KOGYO CO., LTD., JAPAN) --- | 1,15 | |
| A | FR-A-1 270 318 (PERTRIX-UNION) 1961 * claims 1,2B * --- | 1 | |
| A | EXTENDED ABSTRACTS, vol. 93/2, 1 January 1993, page 729 XP000422396 XIA XI: "A STUDY ON THE RECHARGEABILITY OF MODIFIED MN02" * left-hand column, paragraph 1 * * right-hand column, paragraph 2 * --- | 1 | |
| P,X | US-A-5 516 604 (MIECZKOWSKA JOLA E ET AL) 14 May 1996 * claims 1,4; example 5 * * column 6, line 6 - line 28; table 1 * --- | 1-5,11 | TECHNICAL FIELDS SEARCHED (Int.Cl.6) |
| P,X | US-A-5 424 145 (TOMANTSCHGER KLAUS ET AL) 13 June 1995 * claims 1,3,18 * ----- | 1,15 | |
| The present search report has been drawn up for all claims | | | |
| Place of search THE HAGUE | | Date of completion of the search 17 September 1996 | Examiner D'hondt, J |
| <p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>I : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document</p> | | | |